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Mathematical modeling of thin layer drying characteristics of *dika* (*Irvingia gabonensis*) nuts and kernels

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Abstract

The thin layer drying characteristics of *dika* kernels and nuts were investigated at four drying temperatures of 50, 60, 70 and 80 °C and the data was fitted to drying models. Non-linear regression analysis was used to determine model parameters, while coefficient of determination (R^2) and standard error of estimate (SEE) formed the basis for determining the model of best fit. The Modified Henderson–Pabis drying model gave the best fit for the *dika* kernels while the two term model was best for the *dika* nuts. Effective moisture diffusivity ranged from 2.84×10^{-10} m^2/s to 5.06×10^{-11} m^2/s for the kernels and from 1.22×10^{-10} m^2/s to 2.03×10^{-10} m^2/s for the nuts. The activation energies of *dika* kernels and nuts were 16.747 kJ/mol and 37.019 kJ/mol respectively.

Keywords: Moisture content; Temperature; Moisture ratio; Activation energy; Moisture diffusivity

1. Introduction

The domestication of lesser known indigenous plants for subsistence agriculture is playing a major role in enhancing rural livelihoods, mitigating deforestation and environmental degradation in sub-Sahara Africa (Leakey et al., 2005). The *dika* tree (*Irvingia gabonensis*) has high utility value; the leaves, the fruits, the bark, the hardwood and the roots have several medicinal, food and industrial applications (Ndoye et al., 1997; Ayuk et al., 1999). Apart from the common use of the kernels as a soup thickener in West Africa, the kernel oil and meal are potential base materials for pharmaceutical binders, confectionery, edible fat, soap and cosmetics (Ogunsina et al., 2012). *Dika* fruit processing involves fermentation of the fresh fruits in heaped piles for few days and washing the rotten pulp to obtain the nuts. Afterwards, the nuts are sun-dried and cracked to obtain the kernels (Ladipo et al., 1996). As trade in *dika* kernels is on the increase, product quality standard and value addition are becoming prime criteria for setting price for farmers and traders. There is therefore the need to understand unit operations involved in *dika* fruit processing.

The need to preserve more food during peak harvest period, reduce post-harvest losses and equalize availability in-between seasons make artificial drying inevitable in bulk handling of modern food products (Doymaz et al., 2006). Artificial dryers are rapid and provide uniform, hygienic dried product and reduce losses (Karathanos and Belessiotis, 1997; Goyal et al., 2007).

Thin layer drying studies provide the basis for understanding the unique drying characteristics of any particular food material. The results of such studies have been widely used to simulate dryers under deep-bed drying conditions and for quantifying parameters for the design of specialized drying equipment. In thin layer drying, the moisture content of a bio-material exposed to a stream of drying air of known relative humidity, velocity and temperature is monitored over a period of time. A number of mathematical models have been developed to simulate moisture movement and mass transfer during the drying of many agricultural products.

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Table 1
Thin-layer drying models used for the study.

Name	Model	Reference
Newton	$MR = \exp(-kt)$	Ayensu (1997)
Page	$MR = \exp(-kt^n)$	Diamante and Munro (1993)
Modified page	$MR = \exp((-kt))^n$	White et al. (1981)
Henderson and Pabis	$MR = a\exp(-kt)$	Akpinar et al. (2003)
Logarithmic	$MR = a\exp(-kt) + c$	Yagcioglu et al. (1999)
Two term	$MR = a\exp(-k_0t) + b\exp(-k_1t)$	Togrul and Pehlivan (2004)
Diffusion	$MR = a\exp(-kt) + (1-a)\exp(-kbt)$	Yaldiz and Erdekin (2001)
Modified Henderson and Pabis	$MR = a\exp(-kt) + b\exp(-gt) + c\exp(-ht)$	Karathanos and Belessiotis (1999)

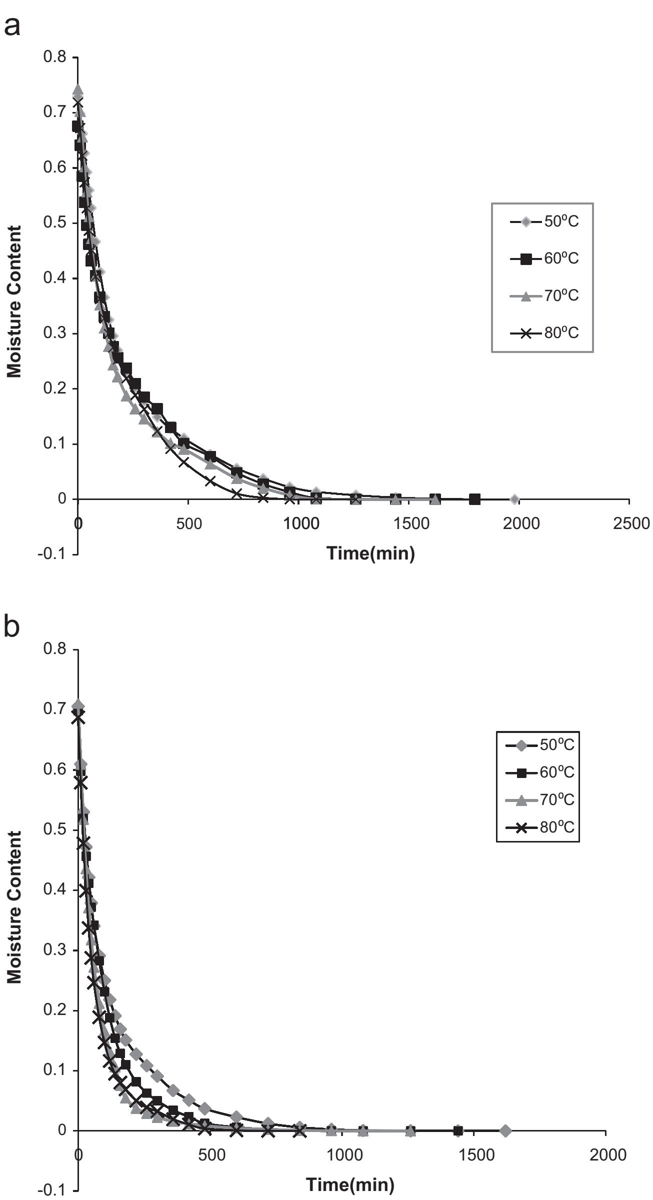

Fig. 1. Moisture content versus time. (a) Nut and (b) kernel.

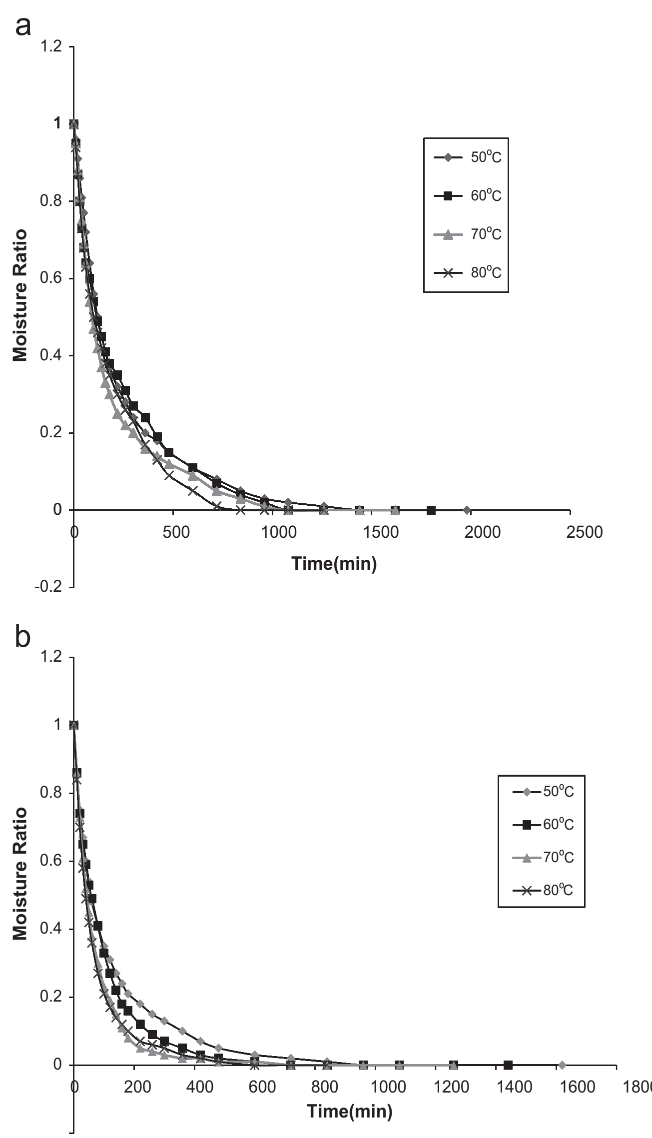

Fig. 2. Moisture ratio versus time. (a) Nut and (b) kernel.

These have been found very useful in understanding drying kinetics and optimization of drying conditions (Vega et al., 2007; Doymaz et al., 2006; Mwithiga and Ochieng-Olwal, 2005).

Although drying is a major unit operation in *dika* fruits processing from nuts to kernels, the literature regarding the drying characteristics of *dika* nuts and kernels are rarely available. Therefore, the objective of this work is to investigate